METHOD AND SYSTEM FOR OF COMPENSATING FOR DATA STORAGE DISC STACK IMBALANCE DURING DISC DRIVE ASSEMBLY

Field of the Invention

This application relates generally to data storage disc drive manufacturing and assembly and more particularly to real time compensation for data storage disc drive imbalance.

Background of the Invention

The static imbalance of data storage disc stack assemblies, usually expressed in milligram-centimetres ("mg-cm"), has recently become a critical performance parameter in disc drive design. This is primarily due to the increasing demand for precision performance in the consumer data storage product market. High imbalance of the disc stack may lead to structural vibration and undesirable noise, both of which are unacceptable in consumer products such as games-boxes and audio-video products. Furthermore, the industry standard specification for drive level imbalance has been reduced from an industry standard, 70 mg-cm to the current state of the art, 50 mg-cm.

The major contributors to the disc stack imbalance of a typical disc drive include disc clamp offset, clamp mass, clamp notch size, motor "MR", and media "MR", where MR is a function of the mass (M) of the media or motor in (mg) x the offset (R) of the media or motor in (cm) from the center of gravity (CG). Of these major contributors, research has shown that the most sensitive contributors that could impact process yield are the clamp offset and the angular orientation or direction of the clamp offset. Clamp offset is defined as the radial distance between the center of the clamp and the center of the spindle motor to which the clamp is attached.

The disc stack typically includes one or more data storage discs clamped onto a motor hub flange via a stamped metallic clamp. The clamp design may also include a spring expansion ring to self-center the clamp with respect to the motor axial centerline. The condition of the machine that is used to assemble the disc clamp onto the stack, the centering of the ring, as well as the clamp shape are all factors that can contribute to the overall stack imbalance. With an industry standard of 50 mg-cm for static imbalance, and with the incoming drive components being at optimum condition, current processes for the assembly of disc drives still have poor process capability. Some of the processes generate 2-9 % of their disc drives at a static imbalance higher

than the 50 mg-cm standard. These imbalances are often compensated for by adding weights or screws to the motor hub or by physically offsetting the data storage discs on the motor hub flange.

Research has shown that the disc clamp offset and the clamp offset angle are two of the most important factors contributing to static imbalance. However, corrective actions typically involve major design changes and added cost such as Active Balancing which requires a design change and the addition of counter-balance weights. These solutions also require extra manufacturing floor space and labor to perform the corrective balancing.

Accordingly there is a need to develop a way of compensating for the disc clamp offset without a major design change or extensive costs. The present invention provides a solution to this and other problems, and offers other advantages over the prior art.

Summary of the Invention

Against this backdrop embodiments of the present invention have been developed. One embodiment is a method of compensating for imbalance in data storage disc stack processing during assembly of the data storage device. The method incorporates an optical measurement system downstream of the disc clamp installation operation. The introduction of a real-time optical measurement system into the assembly line has numerous strategic advantages. The system measures multiple parameters of a most recent set N of incoming disc-stacks produced on the assembly line, where N is a suitable sample size, such as 30 disc stacks. The measured parameters include disc clamp offset, clamp offset angle, ring outer diameter, ring offset, and ring offset angle, where the disc clamp may be installed with a spring expansion ring designed to center the clamp with respect to the axial centerline of the drive motor. The optical capabilities of the system provide quantitative measurement of the install conditions for the clamp and other components, which permits optimization of the components and machine settings. For instance, the optical system may inspect the ring closure condition to avoid reliability issues due to slippage of the disc media.

After measuring parameters for a suitable sample size N, the optical system calculates a dynamic or moving average of the most recent set of N disc stack component offsets and offset angles. The component offsets represent the offsets of the disc stack components from a central point of the disc stack, such as the axial center of the drive motor, and the offset angles represent the direction of the offsets measured from a zero reference mark. The calculated averages are then utilized to determine a component configuration type that will compensate for the imbalance in the next disc stack based on the averages of the most recent N component offsets and offset

angles. For instance, in the case of a disc clamp component, compensating notches cut in the perimeter of the disc clamp are enlarged or added at certain angles on the clamp depending on the average clamp offset and the average clamp offset angle, thus providing multiple clamp configuration types. The optical measurement system determines the optimum clamp configuration type to use on each next installation. The system then feeds back the clamp configuration type to a clamp installation station in the assembly line operation.

During assembly of the next disc stack, the clamp installation station receives and installs the clamp configuration type that compensates for imbalance in that disc stack according to the offset trend. The clamp offset and clamp offset angle of this next assembled disc stack are then measured for use in the next moving average calculation for the most recent N disc stacks produced on the assembly line. This process results in a significantly better balancing process capability and improved product quality throughput. The optical measurement system also recognizes supplier codes printed on the components and can track assembly data such that the calculated averages may be correlated with the machine that installed the clamp and the supplier of the clamp. This enables optimization and comparison of installation equipment settings and component parts.

The above techniques of using optical measurement feedback to selectively install predetermined clamp configuration types to counter balance the disc stack imbalance during disc drive assembly has proven to be effective and feasible. The concept could be extended to the measurement of media and non-symmetrical component offsets with respect to the motor's center axis for achieving further drive balance improvement. These and various other features as well as advantages which characterize the present invention will be apparent from a reading of the following detailed description and a review of the associated drawings.

Brief Description of the Drawings

FIG. 1 is a plan view of a disc drive assembled in accordance with a preferred embodiment of the present invention showing the primary internal components.

FIG. 2 is a cross sectional view through the disc drive in FIG. 1 taken along line 2-2.

FIG. 3 is an operational flow diagram of an assembly process in accordance with a preferred embodiment of the present invention.

FIG. 4 is a model schematic of an optical measurement system for determining and feeding back clamp configurations that compensate for disc stack imbalance in accordance with a preferred embodiment of the present invention.

FIG. 5 is a plan view of a disc clamp and a spring expansion ring configuration, illustrating measurements utilized in an absolute calibration of an optical measurement system in accordance with a preferred embodiment of the present invention.

FIG. 6 is an operational flow diagram illustrating an optical measurement logic flow of an optical measurement system in accordance with a preferred embodiment of the present invention.

FIG. 7 is an operational flow diagram illustrating a clamp configuration type selection logic flow of an optical measurement system in accordance with a preferred embodiment of the present invention.

Detailed Description

A disc drive **100** constructed in accordance with a preferred embodiment of the present invention is shown in FIG. **1**. The disc drive **100** includes a base **102** to which various components of the disc drive **100** are mounted. A top cover **104**, shown partially cut away, cooperates with the base **102** to form an internal, sealed environment for the disc drive in a conventional manner. The components include a spindle motor **106** which rotates one or more discs **108** at a constant high speed. Information is written to and read from tracks on the discs **108** through the use of an actuator assembly **110**, which rotates during a seek operation about a bearing shaft assembly **112** positioned adjacent the discs **108**. The actuator assembly **110** includes a plurality of actuator arms **114** which extend towards the discs **108**, with one or more flexures **116** extending from each of the actuator arms **114**. Mounted at the distal end of each of the flexures **116** is a head **118** which includes a fluid bearing slider enabling the head **118** to fly in close proximity adjacent the corresponding surface of the associated disc **108**.

During a seek operation, the track position of the heads **118** is controlled through the use of a voice coil motor (VCM) **124**, which typically includes a coil **126** attached to the actuator assembly **110**, as well as one or more permanent magnets **128** which establish a magnetic field in which the coil **126** is immersed. The controlled application of current to the coil **126** causes magnetic interaction between the permanent magnets **128** and the coil **126** so that the coil **126** moves in accordance with the well known Lorentz relationship. As the coil **126** moves, the actuator assembly **110** pivots about the bearing shaft assembly **112**, and the heads **118** are caused to move across the surfaces of the discs **108**.

The spindle motor **106** is typically de-energized when the disc drive **100** is not in use for extended periods of time. The heads **118** are moved over park zones **120** near the inner diameter of the discs **108** when the drive motor is de-energized. The heads **118** are secured over the park

zones **120** through the use of an actuator latch arrangement, which prevents inadvertent rotation of the actuator assembly **110** when the heads are parked.

A flex assembly **130** provides the requisite electrical connection paths for the actuator assembly **110** while allowing pivotal movement of the actuator assembly **110** during operation. The flex assembly includes a printed circuit board **132** to which head wires (not shown) are connected; the head wires being routed along the actuator arms **114** and the flexures **116** to the heads **118**. The printed circuit board **132** typically includes circuitry for controlling the write currents applied to the heads **118** during a write operation and a preamplifier for amplifying read signals generated by the heads **118** during a read operation. The flex assembly terminates at a flex bracket **134** for communication through the base deck **102** to a disc drive printed circuit board (not shown) mounted to the bottom side of the disc drive **100**.

FIG. 2 shows a cross sectional view of a disc stack assembly **200** within the disc drive **100** incorporating a preferred embodiment of the present invention. The disc stack assembly includes the spindle motor **106**, the discs **108**, a disc clamp **210** that secures the discs **108** to the spindle motor **106**, and a spring expansion ring **208** designed to self-center the disc clamp **210** with respect to the axial centerline of the spindle motor **106**. The components of the spindle motor **106** include a disc support flange **214** that is pressed fit onto a rotating hub **206** and supports the discs **108**. The rotating hub **206** is mounted via a bearing **204** to a stationery spindle **202**, which is press fit into the base plate **102** of the drive **100**. Stator coils **218** are spaced laterally from the bottom of the rotating hub **206** and permanent magnets **216** are attached and extended from the bottom of the disc support flange **214** just outboard the stator coils **218**. The application of current to the stator coils **218** causes magnetic interaction between the permanent magnets **216** and the stator coils **218** such that the hub 206 rotates about the stationary spindle 202 carrying the discs 108 via the flange 214.

Two of the major contributors to the imbalance of the disc stack assembly is the offset of the clamp **210** center from the axial center of the spindle motor **106** and the direction or angle of this offset. The basic idea behind compensating for imbalance in a disc stack assembly during assembly of the disc drive **100**, is to measure clamp offsets and offset angles for a sample of size N, of the most recent assembled disc stacks, and calculate a moving average of both offset and angle parameters to determine a clamp **214** configuration type (e.g. I, II, III) that will compensate for the moving average offsets and offset angles. The clamp configuration type is then fed back in real time to select and install the selected clamp configuration type on the next disc drive **100**

best suited to balance the disc stack **200 in** accordance with the offset trend. Additional details with regard to the clamp offset, the clamp offset angle, and the compensating clamp configuration type will be described below with respect to **FIGS. 3-7**.

FIG. 3 shows an operational flow diagram of a disc drive assembly process **300** that compensates for disc stack imbalance in accordance with a preferred embodiment of the present invention. Process **300** starts with "BEGIN operation **301**. Control is then passed to operation **302**.

Operation **302** loads the drive spindle motor **106**, including the hub **206** and the flange **214**, onto the base plate **102.** Then the base plate **102,** with the drive motor **106** installed, is loaded onto an assembly line. Control then passes to operation **304** where discs **108** are installed onto the spindle motor **106**. Control then passes from operation **304** to operation **306**.

Operation **306** selects the clamp configuration type **210** to be installed on the disc stack **200**. The operation **306** may receive a predetermined or selected clamp configuration type **210** to be installed from operation **328** once N samples have been measured and averaged in operations **310** and **322** respectively. Next control passes from operation **306** to operation **308** where the selected clamp configuration type **210** is installed onto the disc stack **200**. The clamp **210** is secured with the spring expansion ring **208** during operation **308**. The base plate **102** with the disc stack **200** installed then enters the optical measurement system and control passes to operation **310**.

Operation **310** measures multiple parameters of the disc stack **200** including disc clamp **210** offset, clamp offset angle, ring **208** diameter, ring offset, ring offset angle, and clamp **210** angle. Measurements are optically taken with a digital camera and are transmitted to operation **322** for average calculations as the disc stack **200** continues on to operation **312**.

Operation **322** receives the measurements and calculates a moving or dynamic average for the most recent number of clamp offsets and offset angles that have been measured and transmitted from operation **310**. Control then passes from operation **322** to operation **324** where the calculated averages are updated and stored. Control then passes to determination operation **326**.

Determination operation **326** ascertains whether the most recent N samples have been averaged, where N is a suitable sample size such as 30. If the most recent N samples have not been averaged yet, control branches "NO" back to operation **324**. If the most recent N samples have been averaged, control branches "YES" where operation **328** assumes control.

From the N averaged clamp offsets and offset angles, operation **328** determines the clamp configuration type best suited to improve stack imbalance on the next assembled disc stack **200**. Operation **328** then feeds back the clamp configuration type to operation **306** for use in selecting the clamp configuration type for installation on the next assembled disc stack **200**.

Meanwhile at operation **312**, the stack imbalance of the disc stack **200** advancing from operation **310** is measured. Control then passes to determination operation **314**. Determination operation **314** ascertains whether the disc stack **200** imbalance, measured in mg-cm, exceeds a predetermined threshold value. If the imbalance is greater than the threshold value, control branches "NO" and is transferred to operation **318**. Operation **318** rejects the disc stack **200** and marks the disc stack **200** such that it is no longer processed. Control then passes to determination operation **320**.

If the imbalance is less than or equal to the predetermined threshold value, control branches "YES" and is transferred to operation **316**, where the disc stack **200** is advanced for output and additional processing. Control then passes to determination operation **320**.

Determination operation **320** ascertains whether there are more disc stacks **200** to be assembled. If there are not more disc stacks **200** to be assembled, control branches "NO" to operation **330** where control is returned to other routines at operation **330**. If there are more disc stacks **200** to be assembled, control branches "YES" to operation **302** where a next disc stack begins assembly.

FIG. 4 shows a model schematic of an optical measurement system for determining and feeding back clamp configuration types that compensate for disc stack imbalance in accordance with a preferred embodiment of the present invention. Components of the optical measurement system **400** include a code reader **402** for detecting when a disc stack **200** arrives at the optical measurement work zone and for reading the barcode tags attached to the base of the drive motor 106 for each disc stack **200**. The bar codes identify the serial number and the machine or assembly line install number for each disc stack **200**. Based on the serial number, and through a network database, a computer **404** of the optical measurement system **400** is notified as to whether the disc stack **200** has had a failure at any of the work zones upstream on the assembly line before arriving at measurement system **400**. The bar code will also reference process information through the network database such as information regarding what supplier provided the clamp **210**, drive base **203** or motor **106**. If the disc stack has experienced a failure at a prior work zone or if any of the required process information is not valid or in place, the disc stack will

be bypassed through the optical measurement system **400** and no further processing will occur. The code reader **402** is interconnected with the computer **404** through a standard interface **403**.

The computer **404** controls the entire optical measurement system and receives inputs from and transmits outputs to a computer controlled digital camera **406**, through a transmission control protocol/ internet protocol interface ("TCP/IP") **405**, and a lift and locate programmable logic controller ("PLC") **408** through a standard interface **403**. The PLC **408** controls automation hardware that lifts and locates the disc stack **200** in a position for the digital camera **406** to capture an image of the clamp configuration and offsets. The digital camera **406** is equipped with a back lighting feature to handle reflective clamp surfaces and is interfaced with the PLC **408** through a standard input/output interface **407**. The optical capabilities of the camera **406** also recognize supplier codes printed on components and enable correlation between the measurements and the component suppliers.

FIG. 5 shows a plan view of a disc clamp **210** and a spring expansion ring **208** configuration via an image capture **500**, illustrating measurements utilized in an absolute calibration of the optical measurement system **400** in accordance with a preferred embodiment of the present invention. Image capture **500**, captured by the digital camera **406**, is utilized to calibrate the optical measurement system **400**. Absolute calibration of the system **400** is conducted to ensure precise measurements during the measurement operation. A special marking on the clamp **210** defines the zero reference angular orientation **503**. Subsequent angle measurements will be clock-wise from this zero reference marking **503**. Compensating notch **505**, located at the zero angle reference, is referred to as the center notch **505**. The center notch **505** is usually located at the zero reference angle.

The offset angle is defined as the offset direction of the highest point of the clamp outer diameter **508**. The clamp angle is defined as the orientation of the reference marking **503**. The clamp diameter **508** as indicated above is used to calibrate the pixel count of the digital camera **406** down to, for instance, a resolution of 0.0002 inches. The clamp offset is defined as the radial offset of the center of clamp diameter **508** with respect to the axial spindle motor center or center of gravity **512**. The ring diameter **510** is also captured in the image capture **500** at the four slot openings **507** and the average is taken for calibration. During calibration, apparent measured values of the parameters are compared to actual measured values and a scaling factor is utilized to convert the apparent values to the actual values.

FIG. 6 is an operational flow diagram illustrating an optical measurement logic flow of an optical measurement system in accordance with a preferred embodiment of the present invention. The optical measurement operation **600** measures and computes disc stack parameters that are fed back to the clamp installation operation to identify a clamp configuration type that will compensate for the calculated parameters according to offset trends. The optical measurement and calculation operation, according to a preferred embodiment of the present invention, starts with operation **602**.

In response to a disc stack **200** arriving at an optical measurement work zone or station, the computer **404** sends a command to the digital camera **406** to capture an image of the disc clamp **210** on the disc stack **200**. Control then passes to operation **604**.

Operation **604** reads a fail code associated with the serial number of the disc stack **200**. Control then passes to determination operation **606**.

Determination operation **606**, ascertains whether the disc stack has failed at a previous work zone. If the disc stack **200** has failed at a previous work zone, control branches "YES" and the operation **628** assumes control. Operation **628** ends the optical measurement operation **600** and releases the current disc stack **200**. If the disc stack **200** has not failed at previous or upstream work zones, control branches "NO" and operational control is transferred to operation **608**.

Operation **608** reads a process code associated with the serial number of the disc stack **200**. Control then passes to determination operation **610**. Determination operation **610** ascertains as to whether a disc stack **200** has a process hold for any reason such as lack of a supplier or machine installation code. If the disc stack **200** has a process hold active, control branches "YES" and the operation **628** assumes control. Operation **628** ends the optical measurement operation **600** and releases the current disc stack **200**. If all process indicators are active, control branches "NO" and operational control passes to operation **612**.

Operation **612** captures an image of the disc clamp **210** installed on the disc stack **200** and checks for validity of the image. In response to a valid image being captured control passes to operation **614**.

Operation **614** measures the following disc stack **200** parameters via the computer controlled digital camera **406**: clamp angle, clamp offset, clamp angle offset or orientation, motor center point or center of gravity, ring offset, ring offset angle or orientation, ring diameter, ring concentricity with respect to the clamp **210**, and motor shaft diameter. Operation **614** then

transmits the measured parameters from the digital camera **406** to the computer **404**. Control then passes to operation **616**.

Operation **616** processes the measured parameters by calculating or computing a moving average for the clamp offset of the most recent N disc stacks produced on the assembly line or machine including the disc stack **200** currently in the work zone. The moving averages may be calculated for a certain clamp supplier or vendor code, install machine code, and ring concentricity. Operation **616** computes the dynamic moving average of the clamp offset C in mils with user defined parameters N, k, and i. The data series is smoothed by taking the average readings of the last *N* observations, starting from the observation at time period *t*. A moving average of order *N* at time period *t* is given by the equation (1):

$$C_t = \frac{1}{N}\sum_{j=t}^{t-(N-1)} c_j = \frac{1}{N}\left(c_t + c_{t-1} + \ldots + c_{t-(N-1)}\right)$$

and where C_{ki} represents a two dimensional matrix where "k" is the machine code and "i" is the clamp supplier code. Operational control then passes to operation **617**.

Operation **617** computes the dynamic moving average of the clamp offset angle A in degrees with user defined parameters N, k , and i. The data series is smoothed by taking the average readings of the last *N* observations, starting from the observation at time period *t*. A moving average of order *N* at time period *t* is given by the equation (2):

$$A_t = \frac{1}{N}\sum_{j=t}^{t-(N-1)} a_j = \frac{1}{N}\left(a_t + a_{t-1} + \ldots + a_{t-(N-1)}\right)$$

and where A_{ki} represents a two dimensional matrix where "k" is the machine code and "i" is the clamp supplier code. Operational control then passes to operation **618**.

Operation **618** computes the dynamic moving average of the clamp offset angle delta D in degrees with user defined parameters N, k , and i. The data series is smoothed by taking the average readings of the last *N* observations, starting from the observation at time period *t*. A moving average of order *N* at time period *t* is given by the equation (3):

$$D_t = \frac{1}{N}\sum_{j=t}^{t-(N-1)} d_j = \frac{1}{N}\sum_{j=t}^{t-(N-1)} Absolute(a_j - A_t)$$

and where D_t $(a_j - A_t)$ ranges from +/- (0 to 180), if >180 use (360- $(d_j - A_t)$ is the machine code and "i" is the clamp supplier code. Operational control then passes to operation **619**.

Referring now to **FIG 7**, operational flow **619** selects the optimum clamp configuration type for the next disc stack **200** based on the clamp offset and offset angle trends. Operational flow 619 begins with determination operation **650**. Determination operation **650** ascertains whether the clamp offset angle delta D is greater than or equal to a predetermined maximum angle, or whether the average clamp offset C is greater than a predetermined maximum threshold offset, thus indicating a process experiencing greater-than-expected variation. If C is greater than the maximum threshold offset or if D is greater than or equal to the maximum threshold angle control branches "YES" to operation **670** where operations to shut down the machine for maintenance are initiated. If C is less than or equal to the maximum threshold offset and if D is less than the maximum threshold angle, control branches "NO" and operational control then passes to determination operation 652.

Determination operation **652** ascertains whether the average clamp offset C is greater than a predetermined threshold offset, representing a nominal center of gravity offset, before starting the compensation scheme. For instance, a disc clamp of mass 5000 mg with an average clamp offset of .0015 inches will produce an equivalent imbalance of 19 mg-cm, which is well below the industry standard maximum of 50 mg-cm. Thus a predetermined threshold clamp offset could be set at .0015 inches before the compensation scheme is turned on. If C is less than or equal to the predetermined threshold offset, control branches "NO" and the operation **672** assumes control. Operation **672** selects the original clamp configuration without modification because the clamp offset does not exceed the predetermined threshold offset. If C is greater than the predetermined threshold offset, control branches "YES" to operation **654**.

Operation **654** turns on the compensation scheme because C is greater than the predetermined threshold offset and less than the maximum threshold offset. The compensation scheme determines the desired or optimum clamp configuration type necessary to compensate for imbalance in the next disc stack according to offset trends. The original clamp configuration is modified by enlarging existing notches or placing extra compensation notches in the perimeter or interior surface of the disc clamp **210** within the sector or quadrant of the clamp offset angle, measured clockwise ("CW") from the calibrated zero marking **503**. Control then passes to determination operation **656** to identify the optimum clamp configuration type to compensate for the clamp offset trend.

Determination operation **656** ascertains whether the average offset angle A is within a first sector or quadrant, where the first sector is defined at or within the range of -45 degrees to 45

degrees measured from the zero marking **503**. If A is within the first sector, control branches "YES" to operation **674**.

Operation **674** selects the clamp configuration type where the center notch, located at the zero marking **503,** is enlarged to compensate for the clamp offset. If A is outside of the first sector range, control branches "NO" to determination operation **658**.

Determination operation **658** ascertains whether A is within a second sector or quadrant, where the second sector is defined within the range of greater than 45 degrees and less than 135 degrees. If A is within the second sector, control branches "YES" to operation **676**.

Operation **676** selects the clamp configuration type where an extra compensation notch is placed at 90 degrees from the zero degree marking **503**. If A is outside of the second sector range, control branches "NO" to determination operation **660**.

Determination operation **660** ascertains whether A is within a third sector or quadrant, where the third sector is defined within the range of greater than or equal to 135 degrees and less than or equal to 225 degrees. If A is within the third sector, control branches "YES" to operation **678**.

Operation **678** selects the clamp configuration type where an extra compensation notch is placed at 180 degrees from the zero degree marking **503**. If A is outside of the third sector range, control branches "NO" to operation **680**.

Operation **680** selects the clamp configuration type where an extra compensation notch is placed at 270 degrees from the zero degree marking **503**. Referring back to **FIG. 6A,** control then passes to operation **620**.

Operation **620** updates the database with the measured and calculated parameters and feeds back or transmits the selected clamp configuration type to the clamp installation operation upstream for use on the next disc stack **200**. Control then passes to operation **624**.

Operation **624** updates the fail and process codes based on the disc stack outcome in the optical measurement system **400**. Control then passes to operation **628** where the disc stacks are released and control is returned to other operations.

In summary, the present invention can be viewed as a method (such as shown in operational flow **300**) of compensating for imbalance in a data storage disc stack (such as **200**) within a data storage device (such as **100**) during assembly of the data storage device (such as **100**), the disc stack (such as **200**) having components including a drive motor (such as **106**) having a stationary stator (such as **218**) and a hub (such as **206**) that rotates about a stationary

spindle (such as **202**), the hub (such as **206**) having a disc support flange (such as **214**) supporting one or more data storage discs (such as **108**) secured to the flange by a disc clamp (such as **210**).

The method (such as shown in operational flow **300**) of the present invention can be viewed as comprising the acts of: optically measuring one or more disc stack parameters, including disc stack component offsets and disc stack component offset angles for a most recent N disc stacks (such as **200**) produced on an assembly line; calculating a moving average of the most recent N disc stack component offsets and the most recent N offset angles; utilizing the calculated averages to determine a desired component configuration type; and feeding back the desired component configuration type to a component installation station to select the desired component configuration type for installation in a next disc stack (such as **200**).

The method (such as shown in operational flow **300**) includes determining whether a next disc stack (such as **200**) is to be assembled; in response to the next disc stack (such as **200**) being assembled, receiving and installing the component configuration type to compensate for imbalance in the next disc stack (such as **200**); and optically measuring, with the optical measuring system (such as **400**), the disc stack parameters on the next disc stack (such as **200**). Additionally, the preceding acts, from calculating a moving average of the most recent N disc stack component offsets and offset angles to optically measuring the disc stack parameters on the next disc stack (such as **200**) may be repeated for each subsequent disc stack (such as **200**).

Additionally, the method (such as shown in operational flow **300**) can also be viewed as compensating for disc stack imbalance when a disc stack component comprises the disc clamp (such as **210**) and the disk stack parameters comprise N clamp offsets and N clamp offset angles wherein the clamp offset comprises a radial distance between the axial centerline of the drive motor (such as **512**) and the center of the disc clamp and the clamp offset angle comprises a clamp offset direction measured from a zero reference mark (such as **503**) on the disc clamp (such as **210**).

Furthermore, assembly of the next disc stack (such as **200**) can be viewed as comprising: loading a next drive motor (such as **106**) and motor base (such as **102**) onto the assembly line and installing at least one data storage disc (such as **108**) onto the disc support flange (such as **214**) of the next drive motor hub (such as **206**). Additionally, receiving and installing the component configuration type can be viewed as comprising: receiving, at a disc clamp installation station, a disc clamp configuration type to compensate for imbalance in the next disc stack (such as **200**) and installing the disc clamp (such as **210**) having the predetermined

configuration type over the flange (such as **214**) of the next disc stack (such as **200**) to secure the at least one disc (such as **108**).

Additionally, measuring one or more disc stack parameters on the next disc stack (such as **200**) with the optical measuring system (such as **400**) can be viewed as comprising measuring the clamp offset and the clamp offset angle of the next disc stack (such as **200**) for use in a sample size N calculation for the average clamp offset and average angle. Furthermore, the clamp (such as **210**) can be installed with a spring expansion ring (such as **208**) that is designed to center the clamp (such as **210**) with respect to the axial centerline of the drive motor (such as **512**) and the measured disc stack parameters can be viewed as further comprising a sample size N ring offsets from the axial centerline of a sample size N drive motors (such as **106**) and a sample size N ring offset angles in the direction of the ring offsets.

Additionally, the measured disc stack parameters can further comprise N maximum ring outer diameters (such as **510**); N drive motor center points(such as **512**); and N clamp angles wherein the clamp angles comprise an orientation of the zero reference marks (such as **503**) on the clamps.

The method (such as shown in operational flow **600**) of measuring the next disc stack parameters with the optical measurement system (such as **400**) can be viewed as comprising capturing an image of the next disc stack (such as **200**) with a computer controlled digital camera (such as **406**), measuring the disc stack parameters, and transmitting the measured parameters to a computer (such as **404**).

Furthermore, calibrating the optical measurement system (such as **400**) before measuring the sample size N disc stack parameters can be viewed as comprising: capturing an image of a disc stack component installed on a disc stack (such as **200**); referencing a zero mark (such as **503**) on the disc stack component from which subsequent angle measurements are clock wise; calibrating the disc stack parameters that are measured in the sample size N; selecting and measuring a disc stack parameter multiple times to calibrate a pixel count of a digital camera (such as **406**); comparing apparent measured values of the parameters to actual measured values; and utilizing a scaling factor to convert the apparent values to the actual values.

It will be clear that the present invention is well adapted to attain the ends and advantages mentioned as well as those inherent therein. While a presently preferred embodiment has been described for purposes of this disclosure, various changes and modifications may be made which are well within the scope of the present invention. For example, the concept could be extended to the measurement of media and non-symmetrical component offsets with respect to the motor's

axis for further drive balance improvement. Numerous other changes may be made which will readily suggest themselves to those skilled in the art and which are encompassed in the spirit of the invention disclosed and as defined in the appended claims.